

HYPERFINE INTERACTION IN Gd IN DIAMAGNETIC, METALLIC HOSTS

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Mössbauer effect data for dilute, paramagnetic Gd in the diamagnetic, metallic hosts YAl_2 , YbAl_2 and Al are analysed and yield a local conduction electron polarization contribution to the Gd hyperfine field of +140 kOe.

Hyperfine fields at Gd nuclei in metallic, magnetically ordered materials may be considered to have three main sources [1-3]: (1) core polarization; (2) local conduction electron polarization; (3) neighbor effects, including conduction electron polarization, overlap effects and covalency. The magnitude of contribution (1) may be obtained from measurements of Gd^{3+} hyperfine interactions in diamagnetic insulators (-340 kOe). The magnitude of contribution (2) could be obtained from measurements of Gd^{3+} hyperfine interactions in metallic, diamagnetic hosts, assuming that (1) has the same magnitude in metals as in insulators. In this letter, recent measurements by Persson et al. [4] are analysed to obtain the magnetic field and temperature dependence of the paramagnetic hyperfine structure [5] in Gd^{3+} in the cubic, diamagnetic, metallic hosts YAl_2 , YbAl_2 and Al, and hence contribution (2) in these materials.

Persson et al. [4] measured the splitting between the $\Delta m = +1$ and -1 component of the $2^+ \xrightarrow{E_2} 0^+$ 89 keV transition in ^{156}Gd , for Gd metal and GdFe_2 in longitudinal, external magnetic fields at 4.2°K. The sources were also in the external field at low temperature and the observed splitting is the vector difference of the splitting in the absorber and source,

$$\Delta E = 2g_2 + \mu_N (H_{\text{NS}} - H_{\text{NA}}), \quad (1)$$

where ΔE is the observed splitting, H_{NS} is the field at the nucleus in the source and H_{NA} is the

field at the nucleus in the absorber. The measured splitting gives H_{NS} because [5]

$$H_{\text{NA}} = H_{\text{hfA}} \pm H_0, \quad (2)$$

where H_{hfA} is the hyperfine splitting in the absorber and H_0 is the external field. Gd^{3+} has a $4f^7$ configuration and an $^8S_{7/2}$ ground state; hence we expect the paramagnetic hyperfine field in the source to have a Brillouin function dependence on H_0/T , i.e.,

$$\begin{aligned} H_{\text{hfS}} &= H_{\text{NS}} - H_0^S \\ &= H_{\text{hf}}^S B_{7/2}^S \left(\frac{g\mu_B H_0^S}{kT} \right) \end{aligned} \quad (3)$$

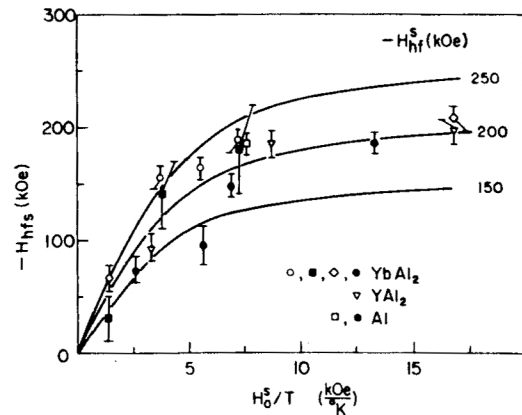


Fig. 1. Hyperfine field at the Gd nucleus plotted as a function of the external field divided by temperature. The solid curves are theoretical (eq. (3)) for three values of the saturation hyperfine field. The data are taken from ref. 4, except \odot taken from ref. 5.

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where H_{hf}^{S} is the saturation hyperfine field and H_0^{S} is the external field at the source. We take the electronic g factor = 2; small g -shifts will not affect the determination of H_{hf}^{S} . In fig. 1, H_{hf}^{S} from the data of Persson [4] are plotted as a function of H_0^{S}/T . The solid curves are calculated from eq. (3), for three values of H_{hf}^{S} . The data for the three hosts follow the Brillouin function behavior reasonably well, and indicate a saturation hyperfine field $H_{\text{hf}}^{\text{S}} = -200 \pm 25$ kOe. Using -340 kOe as the core polarization contribution, this gives +140 kOe as the local conduction electron contribution.

In Gd metal, $H_{\text{hf}} = -300$ kOe [4] and all three contributions to the hyperfine field are present. Hufner [1] and Zmora et al. [3] estimated contribution (2) to be +240 kOe, i.e., almost twice as large as in YbAl_2 , YAl_2 and Al. This change is consistent with a larger change density at the Gd nucleus in Gd metal compared with Gd in the

dilute alloys [6], because the magnitude of (2) depends on the 's'-like electron density of states at the Fermi level.

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